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THE GRAIN SMUTS:

HOW THEY ARE CAUSED AND HOW TO PREVENT THEM.

BY

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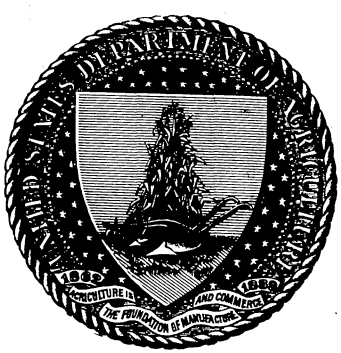

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY,
Washington, D. C., March 9, 1898.

SIR: I have the honor to transmit herewith for publication a detailed article on The Grain Smuts: How they are Caused and How to Prevent Them, and respectfully recommend that it be published as a Farmers' Bulletin. The annual loss from oat smut alone is estimated to be over $18,000,000, and this could be easily saved by adopting the methods of treatment described in this bulletin. Many of the facts herein set forth were published in Farmers' Bulletin No. 5, long since out of print, and in an article by Mr. Swingle published in the Yearbook for 1894. In addition it gives the results of many recent experiments.

Respectfully,

ALBERT F. WOODS,
Acting Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE GRAIN SMUTS: HOW THEY ARE CAUSED AND HOW TO PREVENT THEM.

INTRODUCTION.

To the ordinary observer nothing could seem more unlike a definitely organized plant than the black, dusty mass which fills the kernels of wheat or replaces the entire head of oats attacked by smut, and yet, as a matter of fact, this black dust consists of thousands of germs of a minute parasitic plant, having the same function as the seeds of higher plants. These germs, or spores, are blown about by the wind and are frequently carried from field to field by thrashing machines. Many of the spores lodge on healthy kernels, and when the latter sprout the spores adhering to them germinate and send slender threads into the young plant. Their presence, however, can scarcely be detected until the head begins to develop. At this time the threads fill the flower or kernel, absorb the nourishment intended for the grain, and are soon converted into a mass of spores, and from this mass are blown about and infect the next year's seed.

The enormous amount of damage caused by the smuts has attracted attention ever since the days of ancient Greece and Rome. Only within the present century, however, have remedies been discovered for these parasites, and a description of these remedies, together with a history of the study of smuts, constitute fascinating pages in the records of vegetable pathology.

Two classes of smuts attack our common cereals, viz, the stinking smuts, or bunt, which occur on wheat only, and the loose smuts, which attack wheat, oats, and barley. The stinking smuts have a very disagreeable odor and destroy the kernel only, while the loose smuts are looser and dustier, and destroy not only the kernel but also more or less of the chaff. As the different smuts must be treated differently, it is very important for the farmer to be able to distinguish one from the other. In the following few pages brief descriptions will be given of the different smuts with which the writer is familiar, and also detailed directions for preventing them.

KINDS OF SMUTS.

STINKING SMUTS, OR BUNT, OF WHEAT.

Wheat is attacked by two species[1] of stinking smut. So closely do these species resemble each other, that usually they can be distinguished only by the use of the microscope. The smutted kernels (usually all in the head are affected) are slightly larger and more irregular in shape than healthy grains, are easily broken open, and contain dark-brown powder, the odor of which is so disagreeable and penetrating that even a small per cent of smutted kernels will give a whole bin of wheat this charac-

FIG. 1.—Head of beardless wheat affected with smut.

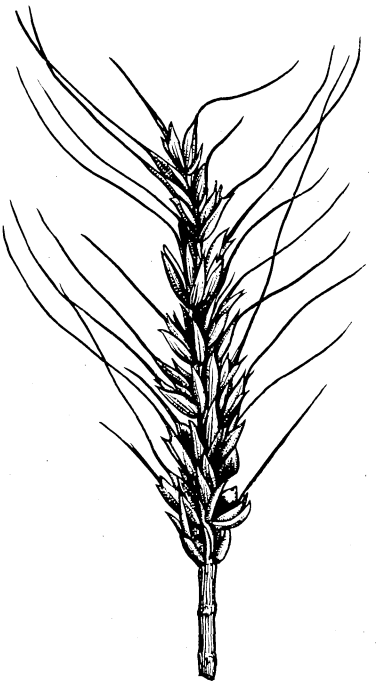

FIG. 2.—Head of bearded wheat affected with smut.

teristic smell. Owing to these characteristics the stinking smuts are easily recognized if present in any considerable quantity. This is not true of any other grain smut. Figs. 1 and 2 show heads of wheat attacked by the stinking smuts.

The stinking smuts occur more or less abundantly in all wheat-growing countries. In the United States they are widely distributed,

[1] *Tilletia fœtens* (B and C.) Schroeter (which is the more common in this country), with globose or oval spores, and *Tilletia tritici* (Bjerk.) Winter, having globose spores, with net-like ridges on the outer surface of the wall. Harwood states that wheat attacked by the latter species has shorter stalks than normal, while that attacked by the former species grows as tall as unaffected wheat.

though fortunately in many regions they are still unknown. There are no accurate statistics as to the amount of damage caused by them. In many localities, however, the losses are very great, and without doubt the losses in the entire United States amount to many millions of dollars annually. In some fields 50 and even as high as 75 per cent of the heads are smutted, and in addition the healthy grain is so contaminated with the fetid spores as to be almost worthless for flour and worse than useless for seed.

If left unchecked, the stinking smuts increase from year to year, until a large per cent of the crop is destroyed. The methods of treatment hereinafter described will enable the progressive farmer to prevent these smuts entirely.

FIG. 3.—Head of wheat affected with loose smut in lower half.

FIG. 4.—Appearance at harvest time of head of wheat affected with loose smut.

LOOSE SMUT OF WHEAT.[1]

This is very different from the stinking smuts. It has no fetid odor; attacks both kernel and chaff; ripens when the healthy wheat is just flowering; and is composed of a loose, dusty mass of spores. At harvest time these spores are usually entirely blown away, the naked stalk where the head should be being the only remaining sign of its action. Fig. 3 shows a head of wheat at flowering time which has been attacked by smut, and fig. 4 shows an affected head at harvest time.

[1] *Ustilago tritici* (Pers.) Jensen. A variety of this smut, which attacks the leaves and sheaths as well as the heads, has recently been reported from Egypt.

Loose smut of wheat is known to occur in Europe, North America, northern Africa, central Asia, and the East Indies. It is found in many parts of the United States, though fortunately in many localities it is rare or entirely absent. The loose smut is not usually as destructive as the stinking smuts, but still often causes a loss of 10 per cent or more of the crop, and has even been reported as destroying as high as 50 per cent of a crop in Michigan. It may be present in considerable amount and yet be entirely overlooked, the smutted heads being reduced to bare stalks at harvest time and there being no trace of it visible in the thrashed grain. The only way to be sure a crop is free from it is to carefully examine the field when the wheat is flowering.

The loose smut is to be feared, not so much on account of the great damage it causes, as of the difficulty in preventing it, for when once introduced into a field it is likely to remain year after year. Wheat growers should therefore be on their guard against this enemy and try to secure seed wheat from fields known by careful examination at flowering time to be free from loose smut. As has long been known, the old bluestone treatments, though often very effective against stinking smuts, do not prevent this species. The ordinary forms of hot-water treatment have also been shown by Kellerman and Arthur to be ineffective. Experiments conducted by Professor Kellerman and the writer, however, showed clearly that certain forms of the hot-water treatment are effective against this smut, but these treatments injure the germinative power of the seed. It can be combated, however, by treating enough wheat to furnish seed for the following year as described on page 14, and this should be done when any considerable per cent of the crop is affected.

LOOSE SMUT OF OATS.[1]

In general appearance this smut is very similar to the loose smut of wheat, and, like that species, ripens when the grain is in flower, and is blown about by the wind. At harvest time the heads are often entirely bare. There is, however, a form of this smut[2] which destroys only the kernel and leaves the outer chaff unaffected. This smut is very hard to detect, since the smutted heads look almost exactly like those that are healthy. When the husk is cut open, however, a mass of smut is found in place of the kernel. Sometimes more than two-thirds of the smut is of this hidden form, and therefore the grower is apt to greatly underestimate the amount present. The appearance at flowering time of heads affected with the ordinary form of this smut is shown in figs. 5 and 6, and their appearance at harvest time is shown in fig. 7.

The loose smut is probably more widely distributed than any of the

[1] *Ustilago avenæ* (Pers.) Jensen.

[2] *Ustilago avenæ, levis* Kell. and Swing. All hidden smuts belong to this variety, but not all *levis* is hidden smut. This variety seems to be what Wille has called *U. kölleri.* Jensen, however, infected oats with covered smut spores and obtained one-sixth completely naked smut.

thousands of species known to students of the group. It is known on every continent and occurs all over the United States. In fact it is an uncommon thing to find a field of oats entirely free from it, and the aggregate amount of damage which it causes is very great. Not one in a thousand of those engaged in growing oats has any adequate idea

FIG. 5.—Head of oats affected with smut, the chaff being only partially destroyed.

FIG. 6.—Head of oats decidedly smutty, but having the chaff only partially destroyed.

FIG. 7.—Final stage of smut, showing condition at harvest time.

of the extent of its ravages. Hundreds of examinations have been made in oat fields in various parts of the United States, and as a result trustworthy estimates have been obtained as to its amount in various localities. Estimates made by Professor Kellerman and the writer put the actual loss in Kansas from oat smut in 1888 at $1,382,328; in 1889, $850,554, and in 1890, $911,299. Dr. Arthur estimates the damage

in Indiana in 1889 at $797,526, and in 1890 at $605,352. Harwood estimates the damage in Michigan in 1891 at $800,000, and in 1892 at $1,000,000. In these States the average of smutted heads varied from 6.5 to 15 per cent. The only State where decidedly lower per cents of smutted oats have been reported is Vermont where in 1892 Jones found an average of 1.6 per cent, or a loss of $26,454.[1] A conservative estimate of the direct loss caused by loose smut would be 8 per cent of the crop, and even at this estimate the loss in the United States is over $18,000,000 annually, averaging $18,504,140 for the years 1890 to 1892.[2] Although this represents the money that would be saved if every smutted head of oats were replaced by a sound one, it does not by any means represent what would be saved by a universal system of seed treatment, as has been conclusively proved, for it must be remembered that it costs as much to raise a badly smutted crop as a clean one, and moreover that the smut does not thin out the stand and give the healthy plants more soil and better light, but the infected plants take up as much room and require as much moisture and nourishment from the soil as do the healthy ones. The loss from smut, therefore, can be said to be taken directly from the profit on the crop, and besides, the seed from badly smutted fields is likely to produce a badly smutted crop the following year, while that from a clean field will produce a crop almost if not entirely free from smut.

By means of several treatments of the seed, described later on, oat smut can be completely prevented and at very little expense. Fortunately both the common and the hidden forms can be eradicated with equal ease.

SMUTS OF BARLEY, RYE, AND CORN.

Barley is attacked by two loose smuts, viz, the covered and the naked forms, both of which are very similar to the loose smut of oats. The spores of the covered smut[3] are often retained till harvest by a thin membrane inclosing the smutted kernel and chaff, while the naked smut[4] is usually all blown away long before harvest. Both these smuts can be completely prevented by the treatment described on page 14.

Smut of rye[5] attacks the leaves and stems of this cereal, sometimes weakening the plants considerably. Jensen thinks this smut can be prevented by treating the seed five minutes with water at 127° F.

Corn smut[6] is widely distributed, but rarely causes more than a frac-

[1] Using the estimates of this Department, putting the value of the crop at $1,626,944 (Ann. Rept. of the Secretary of Agriculture for 1892, p. 420).

[2] Using the estimates made by this Department, putting the average value of the oat crop for these years at $212,797,614 (Ann. Rept. of the Secretary of Agriculture for 1893, p. 483).

[3] *Ustilago hordei* (Pers.) Kell. and Swing.

[4] *Ustilago nuda* (Jens.) Kell. and Swing.

[5] *Urocystis occulta* (Walls.) Rahenh.

[6] *Ustilago maydis* (D. C.) Cda.

tion of 1 per cent loss. No method of preventing it is yet known, although collecting the smutted ears and burning them at the time of husking is doubtless useful in lessening chances of infection the following year.

DIRECTIONS FOR TREATING SEED FOR SMUT.

CORROSIVE SUBLIMATE FOR STINKING SMUTS, OR BUNT, OF WHEAT.

This well-known antiseptic (properly known as mercuric chloride) has been found by Bolley to be efficacious in preventing stinking smut, or bunt, if used at the rate of 1 pound to 50 gallons of water ($2\frac{1}{2}$ parts to 1,000). The following are the directions given for applying this treatment: "Pile the wheat upon the floor or upon a canvas and thoroughly sprinkle or spray on the solution, while the grain is being constantly shoveled over so that every grain becomes wet over its entire surface. Do not use any more of the solution than necessary to do this, as an excess is injurious to seed."

Care must be taken not to allow the solution to touch any metals. Corrosive sublimate is extremely poisonous and may be absorbed by slight wounds on the hands. Seed treated with it is also likely to kill chickens or other animals that may eat it. The greatest caution must be exercised in using this treatment.

COPPER-SULPHATE TREATMENT FOR STINKING SMUTS, OR BUNT, OF WHEAT AND FOR COVERED BARLEY SMUT.

Immerse the grain twelve hours in a solution made by dissolving 1 pound of commercial copper sulphate in 24 gallons of water, after which place it for five minutes in limewater made by slacking 1 pound of good lime and then diluting to 10 gallons with water. This treatment is cheap, simple, and very effective. Grain thus treated, however, does not grow quite as well as that treated with hot water, but the difference in growth is inconsiderable. This treatment is much less efficacious for oat smut.

FORMALIN TREATMENT FOR STINKING SMUTS, OR BUNT, OF WHEAT AND LOOSE SMUT OF OATS.

This substance, used at the rate of 1 pound to 50 to 60 gallons of water, has been found by Bolley and Close to be very effective in preventing these smuts. The formalin of the trade is a 40 per cent solution of formaldehyde, and only this strength should be purchased. The seed should be soaked two hours. The strong formalin is poisonous, but the dilute solution is not dangerous.

HOT-WATER TREATMENT FOR STINKING SMUTS, OR BUNT, OF WHEAT AND FOR OAT SMUT.

Provide two large vessels holding at least 20 gallons each (two wash kettles, soap kettles, wash boilers, tubs, or even barrels will do). One of the vessels should contain warm water at say 110° to 120° F.

and the other hot water at 132° to 133° F. The first is for the purpose of warming the seed before dipping it into the second, as unless this precaution is taken it is difficult to keep the water in the second vessel at the proper temperature. A pail of cold water and a kettle of boiling water should be kept at hand to draw from when necessary to raise or lower the temperature, or, better still, in case a kettle or boiler is used, the temperature of the water may be kept up by placing the vessel over a small fire. Where steam is available, it can be conducted into the second vessel containing the hot water by means of a pipe provided with a stopcock. This answers better than any other method for heating the water and for elevating the temperature from time to time.

Place the seed to be treated, at the rate of half a bushel or more at one time, in a closed vessel which will allow the free entrance of water on all sides. A bushel basket made of heavy wire, with wire netting, say 12 meshes to the inch, spread inside, may be used for this purpose; or a frame can be made at a trifling cost and the wire netting stretched over it. This will allow the free passage of the water and at the same time prevent the seed from passing out. A sack made of loosely woven material—for instance, a gunny sack—may be used instead of the wire basket. In some respects a perforated tin vessel is preferable to any of the above. It is important not to fill the baskets or sacks completely, as the grain is wetted more easily, drains better, and is more uniformly exposed to the hot water when it can move about freely. It is also important to have a volume of hot water at least six to eight times as great as the capacity of the basket or sack, otherwise the temperature varies too much.

In treating wheat it is well to throw the grain into a vessel filled with cold water first, stir it well, and skim off the smutted grains that float on top, and then put the sound grain into the basket or other vessel containing the hot water. This placing in cold water and skimming is entirely unnecessary in treating other grain and even in treating wheat when it is affected by the loose smut only. Dip the basket of seed into the vessel containing the water at 110° to 120°, after a moment lift it, and when most of the water has escaped plunge a second time into the same vessel, and so on several times. The object of the lifting and plunging, to which a rotary motion should be added, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment. Now plunge the basket of seed into the vessel containing water at 132° to 133°. Should the thermometer indicate that the temperature of the water is falling, add to it from the kettle of boiling water until the right heat is attained, or, should the temperature rise higher than 133°, add a little cold water. Should the temperature rise as high as 135°, the time of treatment should be reduced, as five minutes at this temperature suffices to kill the smut, and immersion for a longer time is likely to injure the seed. In all cases the water should be well stirred whenever either hot or cold water is added.

Very soon after its immersion in the second vessel, containing the hot water, the basket of seed should be lifted and drained, after which it should be plunged in again and agitated as above described. This operation should be repeated six or eight times and continued ten minutes. In this way every portion of the seed will be subjected to the action of the hot water. In practice it will be found best for one man (or boy) to devote his entire time to keeping the water at the proper temperature, adding a little hot water if the temperature falls below 132° and a little cold water if it rises above 133°.[1] The entire time of another man will be required in handling the grain to be treated.

After removing the grain from the hot water, spread on a clean floor or on a piece of canvas to dry. The layer of grain should not be over 3

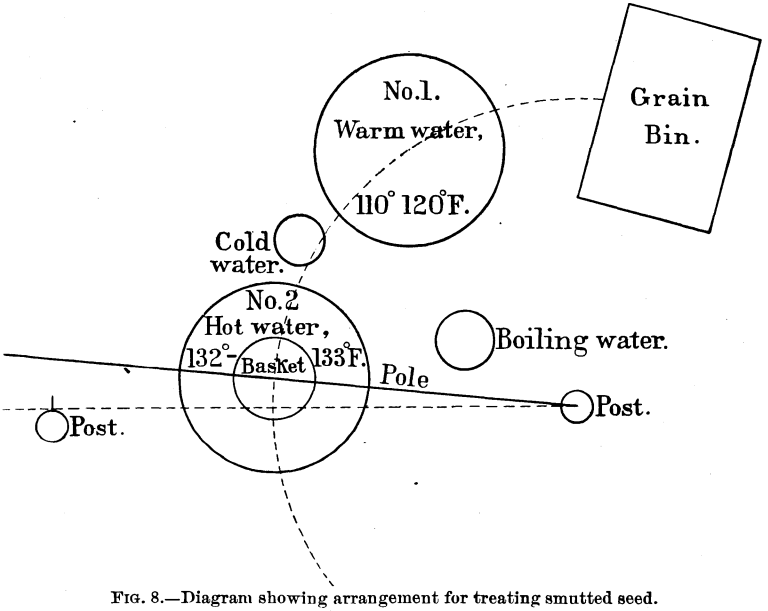

FIG. 8.—Diagram showing arrangement for treating smutted seed.

inches thick. If it can not be spread out at once, dip in cold water and set to one side until it can be attended to. It dries best if spread while hot. After one portion is spread out another can be treated, and so on, until all the seed has been disinfected. More detailed directions for drying treated seed will be found on page 16.

A good arrangement for hot-water treatment is shown by fig. 8. A pole or beam having a hole at one end is passed over a peg in the top of the first post. The hole should be large enough to allow the pole to be moved up and down and sidewise. By swinging the pole around, the basket can be filled at the bin, then immersed a moment in vessel No. 1, and then swung over to vessel No. 2, where the grain is

[1] A good thermometer should be used, preferably one in which the bulb is protected against injury from striking the sides of the vessel. The large thermometer used in dairy work is a very good one for this purpose.

treated ten minutes. Every minute or so the basket must be raised entirely out of the water and allowed to drain. The pole can be supported on a peg or fork in the second post while the basket is draining. Finally the pole is lifted entirely over the second post and the grain removed and spread out to dry. Of course this arrangement of posts and pole is unnecessary except where large amounts of seed are to be treated.

There are many possible modifications of the hot-water treatment that are more easily used than the one here given, but wherever they have been tested on a large scale they have proven uniformly less successful in preventing smut than the method described, and do not give as great an increase in yield.

The important points to be remembered in the hot-water treatment are as follows: (1) Maintain the proper temperature of the water (132° to 133° F.), in no case allowing it to rise higher than 135° or fall below 130°; (2) see that the volume of hot water is at least six or eight times greater than that of the seed treated at any one time; (3) never completely fill the basket or sack used for treating the seed, but always leave room for the grain to move about freely; (4) leave the seed ten minutes in the vessel of hot water.

HOT-WATER TREATMENT FOR LOOSE SMUT OF WHEAT AND FOR BARLEY SMUTS.

In treating wheat for loose smut, soak the grain four hours in cold water, set away for about four hours more in wet sacks, and finally treat as directed above, but only for five minutes, in water at 132°. In planting use one-half more seed per acre, to compensate for that killed by the treatment.

For preventing the two smuts affecting barley, the grain should be soaked as directed above and treated five minutes in water at 130°, or 2° lower than for wheat. This treatment does not injure the seed.

POTASSIUM-SULPHIDE TREATMENT FOR OAT SMUT.

Dissolve 1½ pounds of potassium sulphide in 25 gallons of water in a wooden vessel (a tight barrel serves very well for this purpose). The potassium sulphide should be of the fused form known as liver of sulphur. This can be obtained of any druggist for from 25 to 50 cents per pound, according to the quantity purchased. It should be kept protected from the air in a tight glass vessel until ready for use. The lumps of potassium sulphide dissolve in a few minutes, making the liquid a clear yellowish-brown color. After thoroughly stirring, put into the solution about 3 bushels of oats, and agitate well, to insure wetting every grain. The solution must not only cover the grain, but must rise several inches above it, as some of it is soaked up by the grain. Leave the oats in the solution for twenty-four hours, stirring several times during the day to make sure that every kernel is wetted, after which spread out to dry. A number of experimenters have found

that soaking the seed two hours in a 2 per cent solution (8 pounds to 50 gallons) was nearly or quite as effective as the longer treatment. The grain should be stirred repeatedly to insure thorough wetting. Seed thus treated is much easier to dry than that soaked twenty-four hours. Probably this form of treatment will prove the best.

In treating large quantities of seed a hogshead or a wooden tank might be used. The solution should be kept well covered, to keep the air from it, and should not be used more than three times. In no case should metal be allowed to come in contact with it. This treatment is thoroughly effective for loose smut of oats, and is worthy of a trial for stinking smut of wheat.

Ceres powder, a substance advertised as a preventive of smuts, is, according to the analyses of Hollerung and other German investigators, only crude potassium sulphide sold under another name and at a much higher price.

SAR[1] SOLUTION FOR OAT SMUT.

This fungicide, here announced for the first time, is composed principally of sodium sulphide instead of potassium sulphide, as in the above treatment. It is much cheaper than the potassium sulphide, is more convenient to keep and to use, and has proved equally as effective. However, it has not been tested extensively for smuts, but will doubtless prove effective. It is prepared as follows: Place 15 pounds of flowers of sulphur in a barrel, mix thoroughly with it one-half pound of finely powdered resin, and stir well with 3 quarts of water, which should make a thick paste. The paste must not be thin and watery, nor so dry as to crumble to powder when stirred. Then add 10 pounds of caustic soda[2] and stir well. After from three to fifteen minutes the mass turns a reddish brown and boils violently, and must be stirred well, preferably with a broad paddle, to prevent it from running over. After it has ceased boiling, add slowly about 2 gallons of water (hot if possible, but cold will do) and then carefully pour off into another vessel marked to hold 6 gallons and add hot water till the 6-gallon mark is reached. This gives a stock solution, which must be kept in tightly corked jugs or in closed barrels or kegs, since it spoils if it comes in contact with the air. It is also decomposed if it touches metals. Of this stock solution use 1½ pints to 50 gallons of water, soaking the seed twenty-four hours, or 1 gallon to 50, soaking two hours. In either case treat the seed according to the directions given for the potassium-sulphide treatment.

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[1] In order to give this new fungicide a short name, the word sar has been adopted, being coined from the first letter in each of the words sulphur, alkali, and resin.

[2] Finely powdered concentrated lye sold in grocery stores in 1-pound packages, such as the Red Seal granulated lye, serves admirably. If considerable quantities of the solution are to be prepared, it will be cheaper to purchase powdered caustic soda, 98 per cent pure, in 10-pound tins, through some wholesale dealer in drugs or chemicals.

DIRECTIONS FOR DRYING TREATED SEED.

Spread the grain in a layer 2 or 3 inches deep and shovel over twice a day. A clean floor is a good place on which to dry the grain, but it is better to put it on canvas sheets, about 5 feet by 12 to 15 feet, spread in the sun upon lattice work a few feet from the ground, as this greatly facilitates drying. In the latter case the sheets, with the grain, can be taken in at night. Such sheets of the heaviest ducking should not cost over $1.75 each and can be used for years. The grain can be sown broadcast long before being thoroughly dry, but in case a drill is used must be nearly dry. The seed may be treated months before being used if well dried before being stored. In the case of wheat affected with the stinking smut, or bunt, there is danger of the seed becoming reinfected by contact with the living spores, but in the case of other smuts there is little danger. In treating wheat for stinking smut all tools and sacks should be disinfected, and in case a floor is used in drying the seed it should first be washed with a solution of bluestone (1 pound to 10 gallons of water) before spreading the grain. Canvas sheets and sacks can be easily disinfected by plunging them into boiling water.

EXTRA INCREASE IN YIELD AS A RESULT OF SEED TREATMENT.

One of the most remarkable and unexpected results of the hot water and potassium-sulphide seed treatments, especially of oats, is an increase in the yield beyond the amount that would result from merely replacing every smutted head with a sound one. This extra increase was noticed first by Professor Kellerman and the writer in experiments made with oats in 1889, the hot-water treatment in this case increasing the yield more than twice what would be calculated from the per cent of smut in adjoining untreated plats. This remarkable result was obtained in all subsequent trials and was also noted by Jensen and Arthur. In the various experiments of the investigators named the extra increase in yield ranged from one-half to six times the amount to be expected from replacing the smutted heads with sound ones, and in even higher proportions when the percentage of smut was small. On an average the increase in yield has been found to be double or treble what would result from suppressing the visible smut. In consequence of this remarkable benefit, comparable with what Mr. Galloway has shown to occur where Bordeaux mixture was used on the potato and on some other plants, it will undoubtedly be profitable to treat oats for seed when only 1 or 2 per cent of the heads are smutted.

When used for seed oats, the potassium-sulphide treatment has uniformly given a large extra increase in yield, the increase being almost equal to that resulting from treating seed with hot water. The copper-sulphate and lime treatment gives no extra increase whatever in the case of oats.

Jensen found a similar extra increase as a result of treating seed barley with hot water, and Professor Kellerman has reported an extra

increase in yield from treating wheat for stinking smut with hot water and also with several copper compounds. In Kellerman's experiments there was, however, an enormous amount of smut present in many of the untreated plats, reaching 75 to 80 per cent. Where only a small per cent of smut is present in seed wheat, it is probable that little if any extra increase in yield would result from treating it.

As to the cause of the extra increase in yield, as a result of seed treatment, opinions are divided. It is probably due in part to an increased germinative power of the seed, causing them to sprout sooner and the young plants to grow faster. It has been shown that oats treated with hot water germinate much more quickly than do untreated oats, even if the grain has been dried. Professor Kellerman has shown that potassium sulphide treatment has the same effect on both oats and corn, and further, that seed which had been treated with hot water or potassium sulphide germinated quicker, even after five and a half months, than untreated seed. Dr. Arthur claims that this hastened germination is due to the liberation at once of large quantities of diastase by the action of heat, enabling the young plant to quickly avail itself of the reserve of starch stored in the seed. This does not, however, account for the action of potassium sulphide. Another possible explanation of the observed extra increase in yield has been put forth by Jensen—that is, that the smut may attack many plants, simply weakening and stunting them without even developing its spores in the head. Such injury would of course be prevented by any treatment that kills all the smut adhering to the grain.

DUTY OF SEEDSMEN.

It is confidently believed that by means of the improved methods of seed treatment described the enormous losses from the grain smuts will eventually be prevented to a great extent. Each successive year a greater number of growers treat the grain intended for planting, and often many profit by purchasing clean seed from the crops grown from treated seed. It is hoped that all reputable seed firms will treat, in accordance with the directions given, all grain they expect to sell for seed. Oats purchased at high prices have been known to yield crops more than half of which was smutted. In Kansas, in 1890, Professor Kellerman and the writer found that nearly one-fourth of the varieties of oats grown from seed obtained from dealers was badly smutted, one-fifth of the variety showing over 11 per cent of injury and one-tenth over 20 per cent. In the case of other cereals the danger exists in even greater degree, for instance, the wheat smuts do not occur at all in some regions, but can be readily introduced by seed obtained from infested fields.

SUMMARY.

(1) Smuts of cereals are caused by minute parasitic fungi, the spores or seed-like bodies of which form the black, dusty mass which takes the place of the kernels or the entire head.

(2) The spores are very minute and are easily blown about, often adhering to the kernel before it is planted. When such kernels sprout the spores also germinate and send delicate threads into the young seedlings. These threads follow the growth of the plant, fill the head as soon as formed, and there develop a mass of spores instead of kernels.

(3) The stinking smuts, or bunt, attack the kernels of wheat, filling them with a mass of fetid spores. These smuts cause great damage, but are easily prevented by treating the seed.

(4) Loose smut of wheat attacks the whole head and converts it into a mass of loose, dusty spores. It causes considerable damage in some localities and is more difficult to prevent than other smuts.

(5) Loose smut of oats is very similar to loose smut of wheat and probably causes an annual loss in the United States of more than $18,000,000.

(6) Barley is attacked by two smuts and rye by one. Corn smut is widespread, but fortunately it usually causes only very slight loss. As yet no effective remedy is known for corn smut.

(7) It has been found that stinking smut of wheat can be prevented by treating the seed with corrosive sublimate, 1 pound to 50 gallons of water. The seed is piled on a floor or on canvas and thoroughly sprinkled, every grain being wetted over its entire surface. Corrosive sublimate is poisonous and great care should be exercised in using it.

(8) Stinking smut of wheat and covered barley smut can be prevented by soaking the seed twelve hours in a solution made by dissolving 1 pound of commercial copper sulphate in 24 gallons of water and then immersing the seed for five minutes in limewater.

(9) The formalin treatment has been found very effective in preventing stinking smuts of wheat and oat smut. It consists in soaking the seed for two hours in a solution of 1 pound of formalin to 50 to 60 gallons of water. The strong formalin is poisonous, and great care should be exercised in its use.

(10) The stinking smuts of wheat and oat smut can also be prevented by treating the seed with hot water at 132° for ten minutes.

(11) Loose smut of wheat and barley smuts can be prevented by soaking the seed in cold water for four hours, allowing it to stand four hours more in wet sacks, and then treating for five minutes in water at 132°.

(12) The potassium-sulphide treatment is thoroughly effective for loose smut of oats. It consists in soaking, say, 3 bushels of seed for twenty-four hours in a solution of 1½ pounds of potassium sulphide to 25 gallons of water. Liver of sulphur should be used and the solution should be kept in a tightly closed vessel to protect it from the air.

Soaking the seed two hours in a 2 per cent solution (8 pounds to 50 gallons of water) has been found by a number of experimenters to be almost if not equally as effective as soaking for a longer time in the 1½ pounds to a 25-gallon solution.

(13) A cheaper and more convenient remedy for oat smut and one which it is believed will prove equally as effective, is the sar solution made as described on page 15. The seed should be soaked twenty-four hours in a solution made by using 1½ pints of the stock sar solution to 50 gallons of water, or two hours in a solution of 1 gallon of the stock solution to 50 gallons of water.

(14) To dry the grain after any of the treatments described spread it on a clean floor, or on canvas sheets spread in the sun, preferably on a raised lattice work, say, 2 or 3 inches deep, and turn it over at least twice a day.

(15) In treating oats for smut by either potassium sulphide or hot water an increase in yield is obtained beyond and above the amount that would result from replacing the smutted heads with sound ones. The increase in yield from seed treatment is usually two or three times as much as the apparent loss from smut in untreated fields.

(16) Seed dealers should treat all cereals offered for sale both to increase the yield and to prevent the introduction of smuts into localities where they are yet unknown.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C.

[Only the bulletins named below are available for distribution.]

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No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
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